Comparison of Pilot and Automation Generated Conflict Resolutions

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Overview

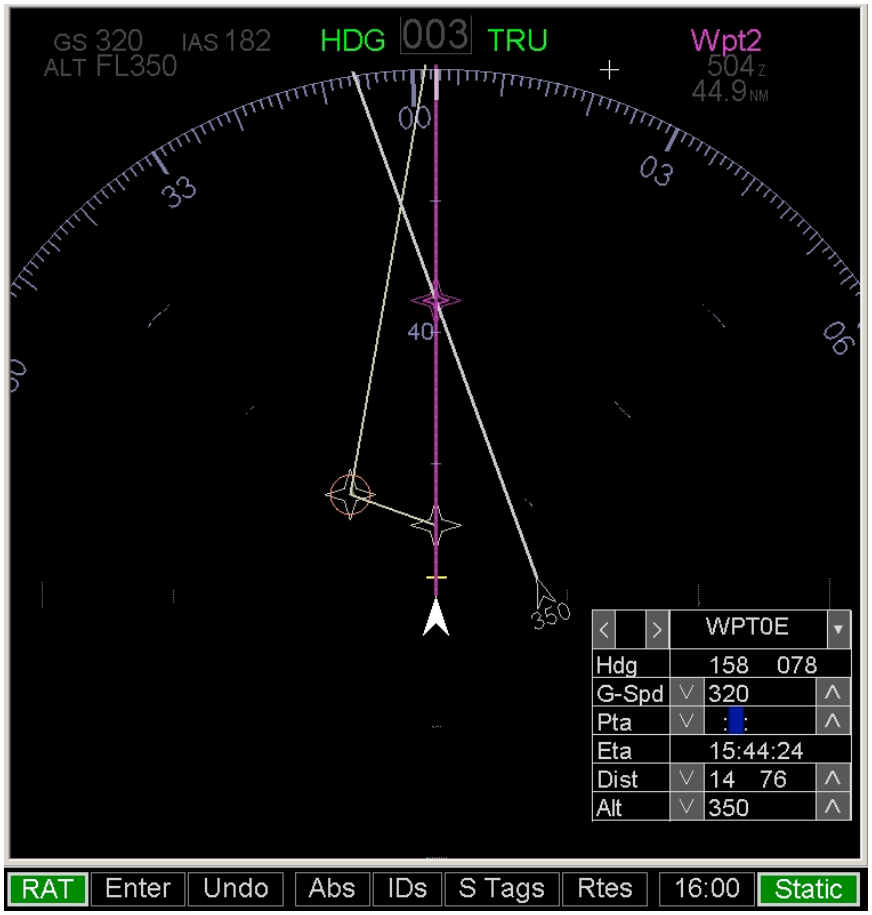
- Motivation
- Pilot Tools
- Experiment Design
- Automation Algorithm
- Results
- Conclusions

Motivation

- Free Flight operational concepts (e.g., DAG-TM) propose to shift some separation responsibility to flight deck
  - Flight crew will need decision support tools for separation assurance
- Separation assurance can have various levels of automation
  - Full automation can reliably solve conflicts with complex geometries
  - Partial automation permits pilots to adapt to unforeseen circumstances
- Automation should be consistent with pilot's framework
  - Pilot's framework reflects biases and strategies for the task at hand
- Primary goal of study: Conduct qualitative and quantitative comparisons of pilot and automation generated resolutions
  - Secondary goal: Examine effect of different levels of pilot aids

Route Analysis Tool (RAT)

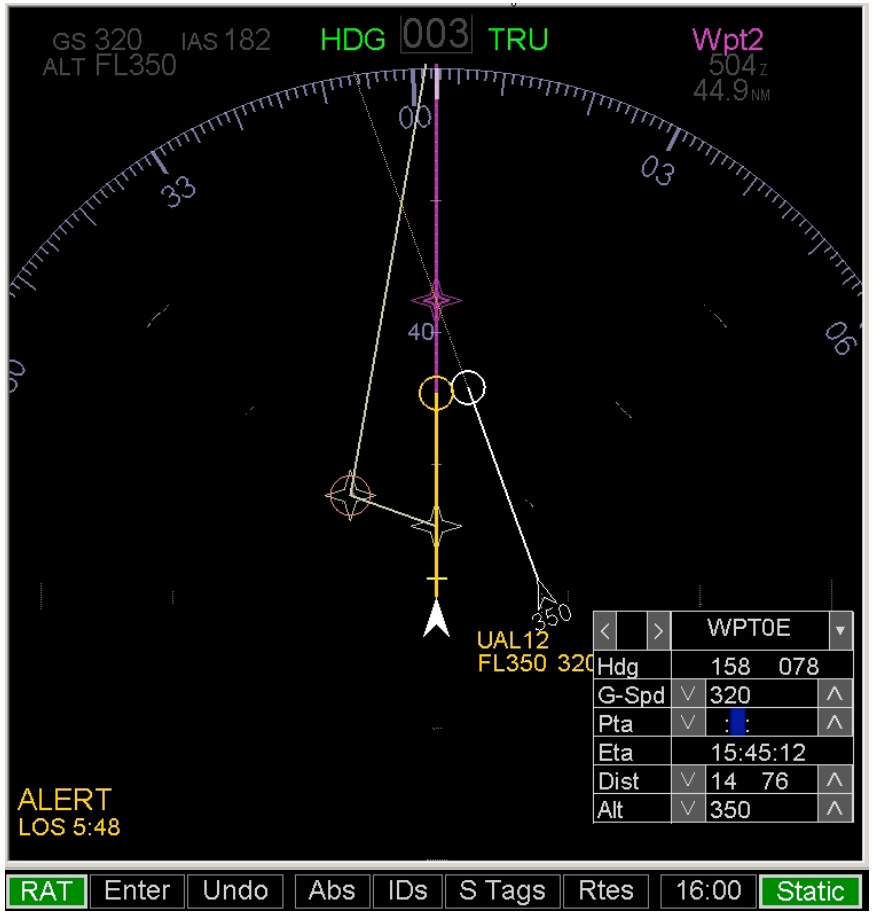
- Augments the basic Cockpit Display of Traffic Information (CDTI)
- Enables pilot to graphically replan flight path and load it directly into FMS
- Graphical Path Replanning
  - Core function that enables graphical construction of new route
  - Does not provide pilot with any guidance for conflict resolution



Conflict Resolution Aids in RAT

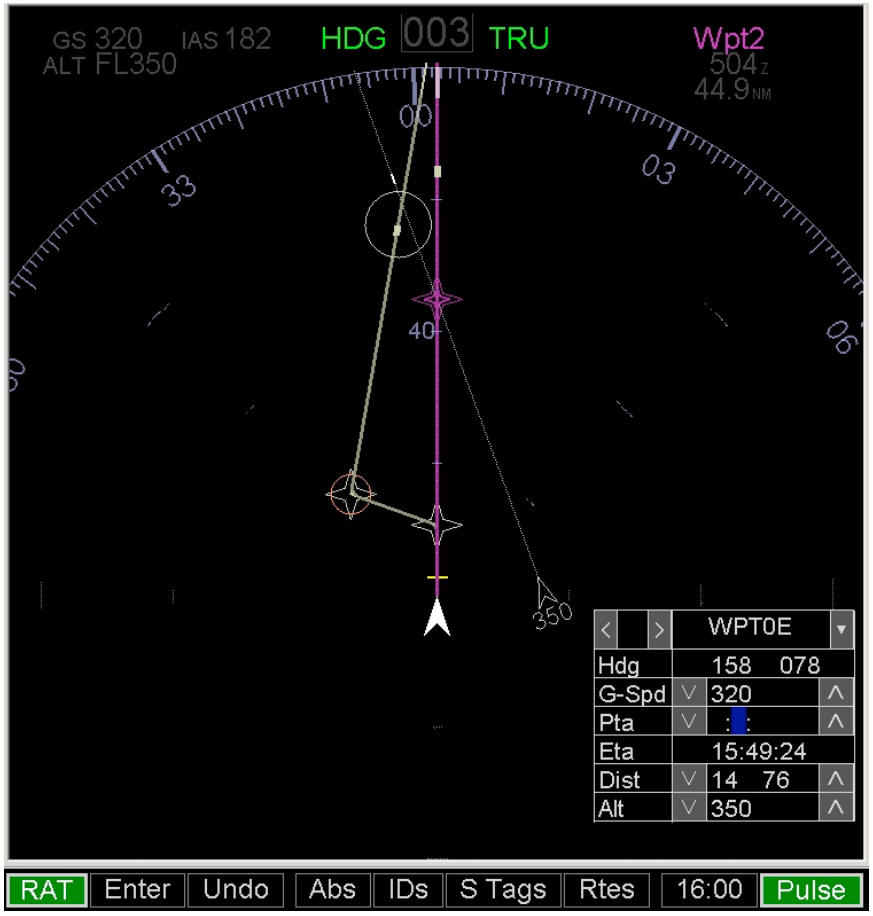
Dynamic Conflict Alerting

Informs pilot if proposed route is conflict-free



Dynamic Trajectory Pulse Prediction

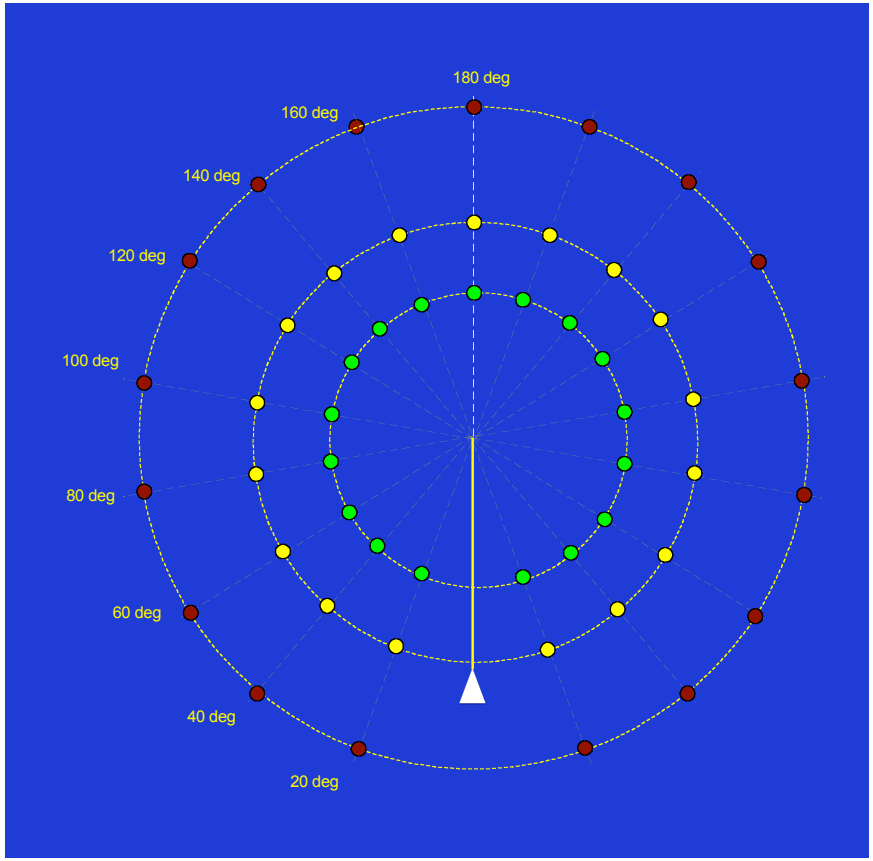
Provides awareness of horizontal separation along proposed route



Demo of Route Analysis Tool (RAT)

Experiment Design (1 of 2)

- Scenario Variables
  - Conflict Angle
    - » 20 to 180 deg (9 values)
  - Ownship Distance to collision point
    - » 30 nm (near)
    - » 45 nm (mid)
    - » 60 nm (far)
  - Intruder Speed
    - » 220 kts (slow)
    - » 320 kts (equal to Ownship)
    - » 480 kts (fast)



- Pilot Display Variable
  - Availability of Resolution Aids
    - » No Resolution Aids (only Graphical Path Replanning function available)
    - » With Resolution Aids

Experiment Design (2 of 2)

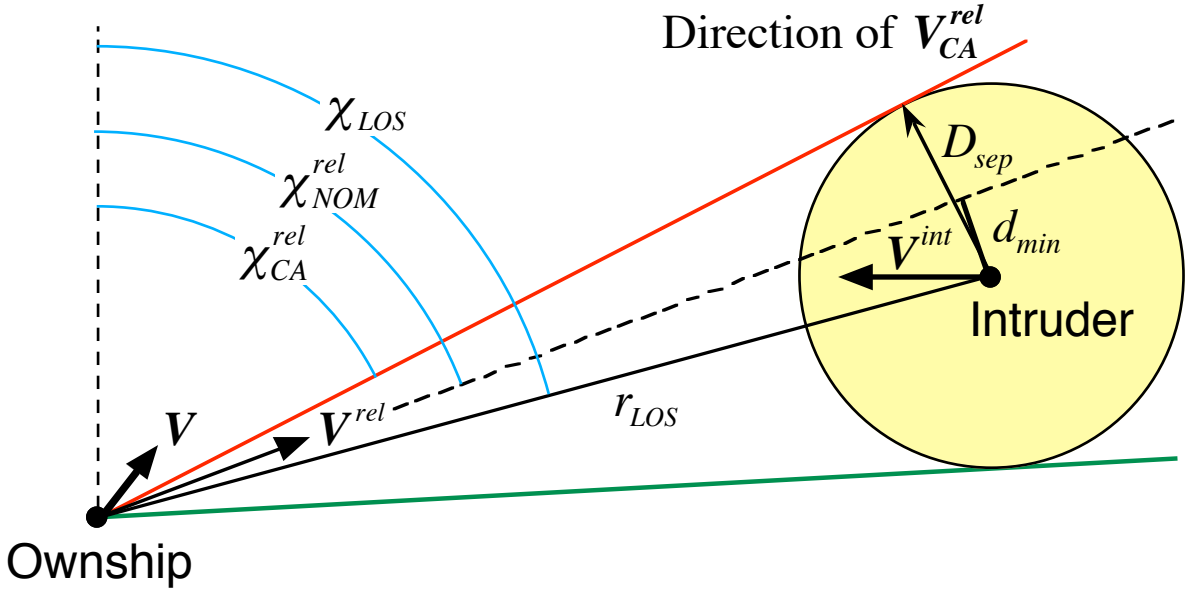
- Task: Solve the presented traffic problem, with three goals
  - Safety: Eliminate conflict *(Most Important)*
  - Efficiency: Minimize added path length *(Secondary Importance)*
  - Timeliness: Determine solution as quickly as possible *(Least Important)*

- Participants
  - Eight general aviation pilots
  - Flight instructor rated (at least 250 hrs flight experience)

- Analysis Variables
  - Conflict Resolution Rate (how often resolution was successful)
  - Separation Distance at Closest Approach
  - Cost of Resolution (path length added by resolution)
  - Response Time
  - Turn Direction

Algorithm for Automation Resolutions

- Geometric Optimization approach to conflict resolution
  - Seeks to minimize deviations from nominal trajectory
  - Geometric characteristics of aircraft trajectories are utilized to derive closed-form analytical expressions for efficient conflict avoidance

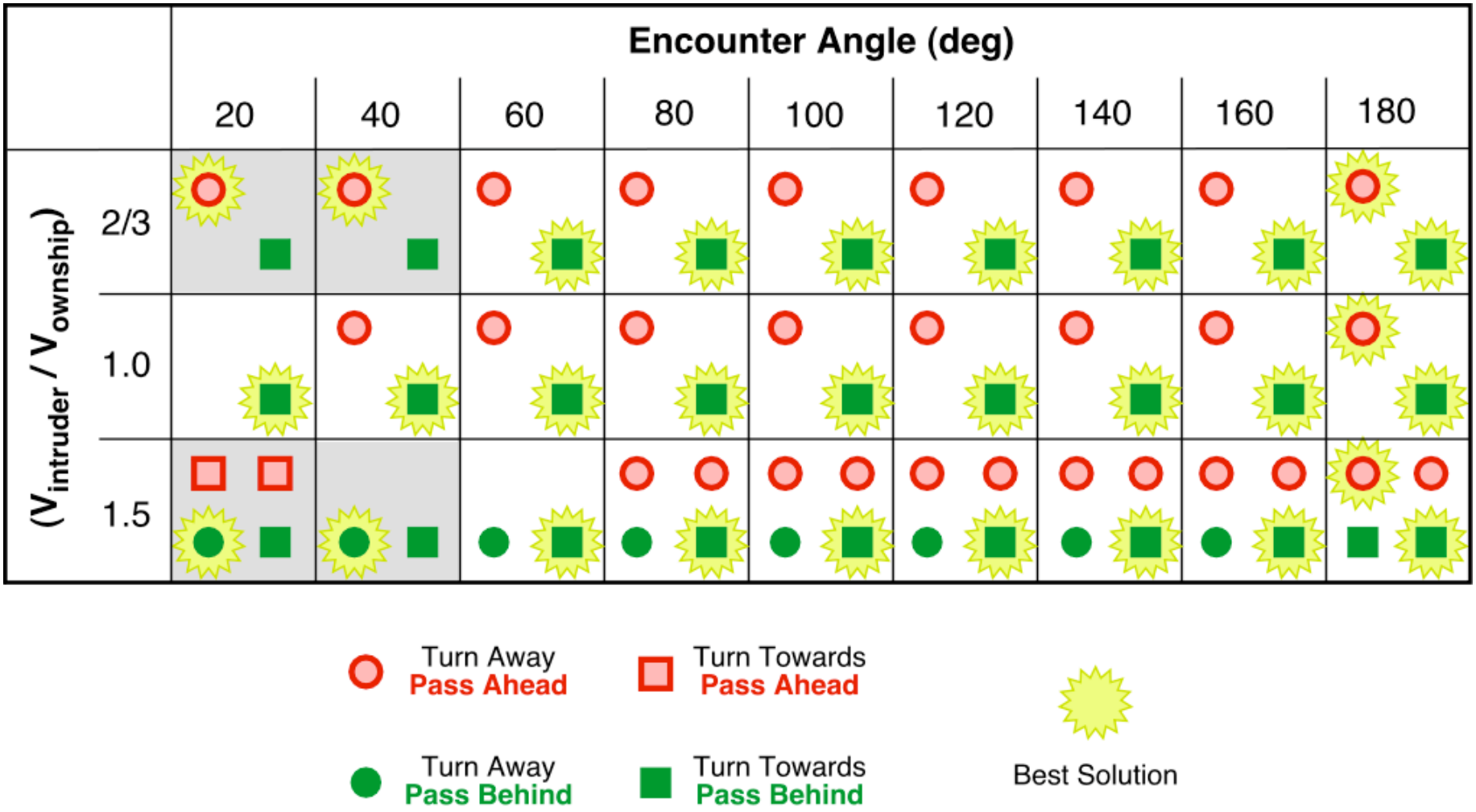


$$\chi_{CA} = \chi_{CA}^{rel} - \sin^{-1}\left\{ \frac{V^{int}}{V} \sin(\chi_{CA}^{rel} - \chi^{int}) \right\}$$

Bilimoria, K.D., "A Geometric Optimization Approach to Aircraft Conflict Resolution," Paper No. 2000-4265, *AIAA Guidance, Navigation, and Control Conference*, August 2000.

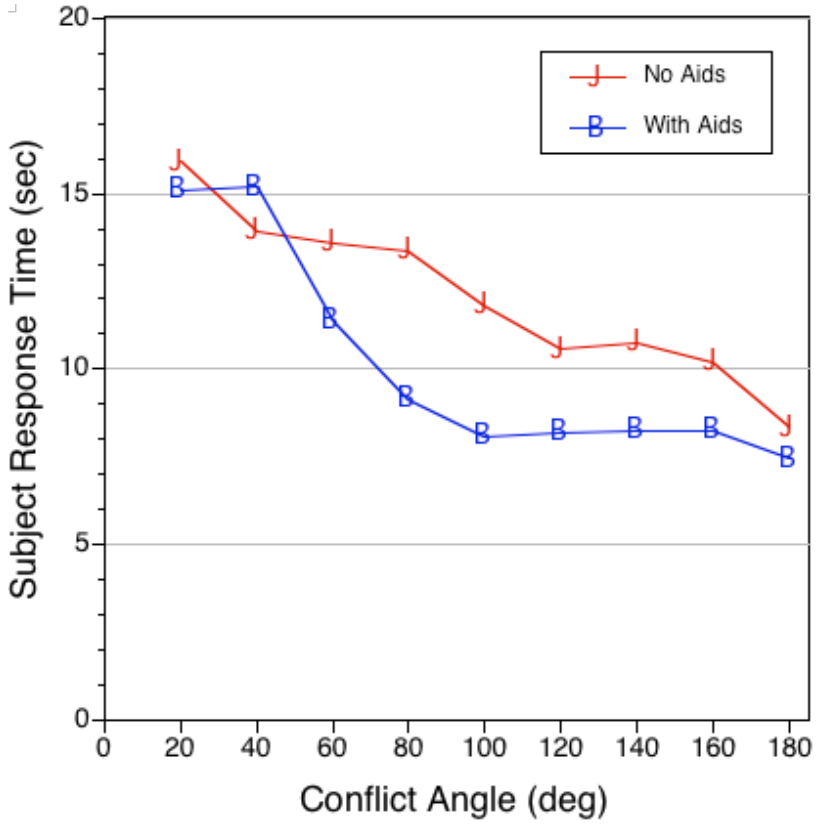
Characteristics of Automation Resolutions

Ownship distance from collision point is 60 nm

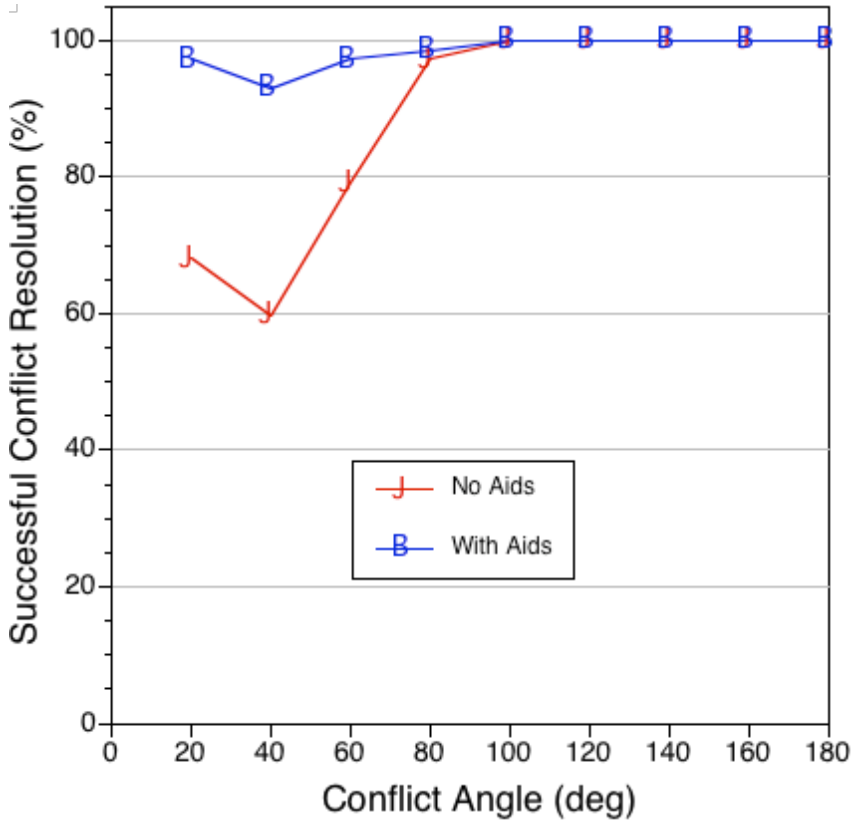


Pilot Generated Resolutions

Response Time

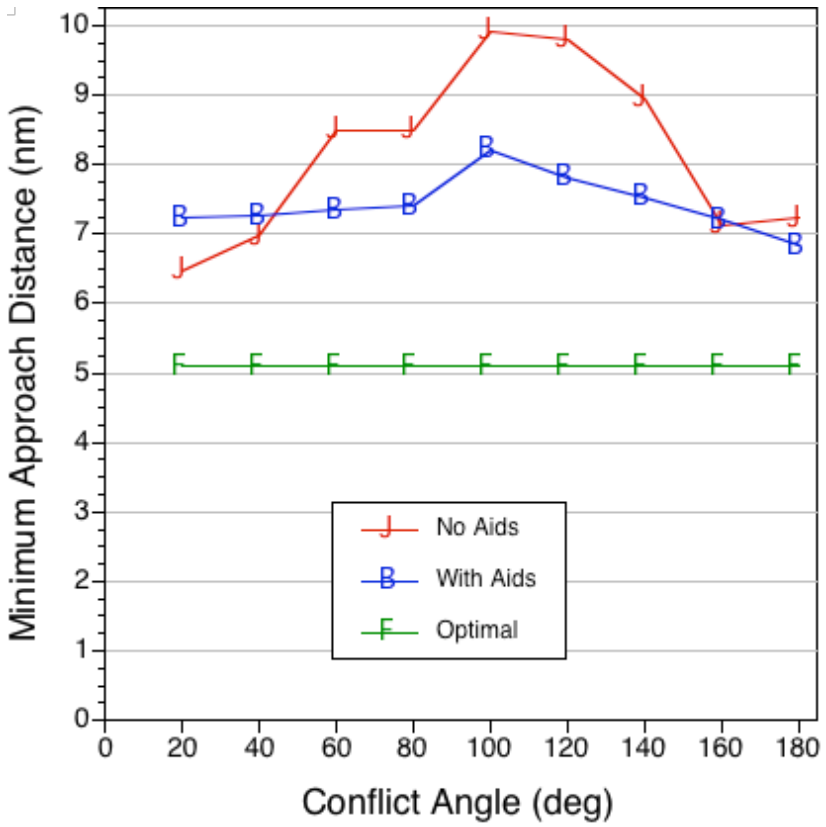


Success Rate

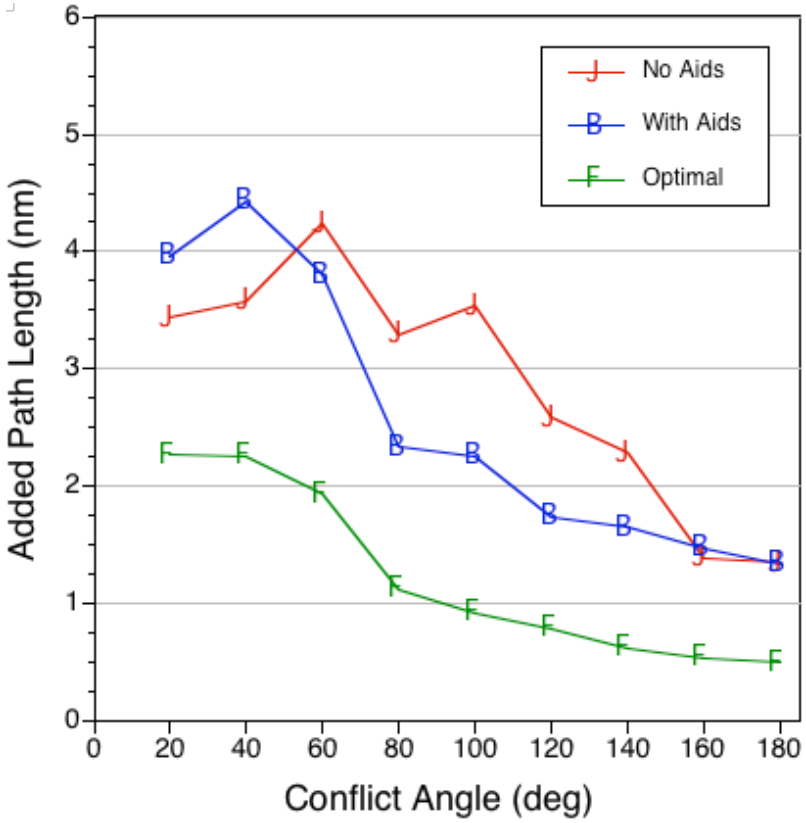


Pilot and Automation Generated Resolutions

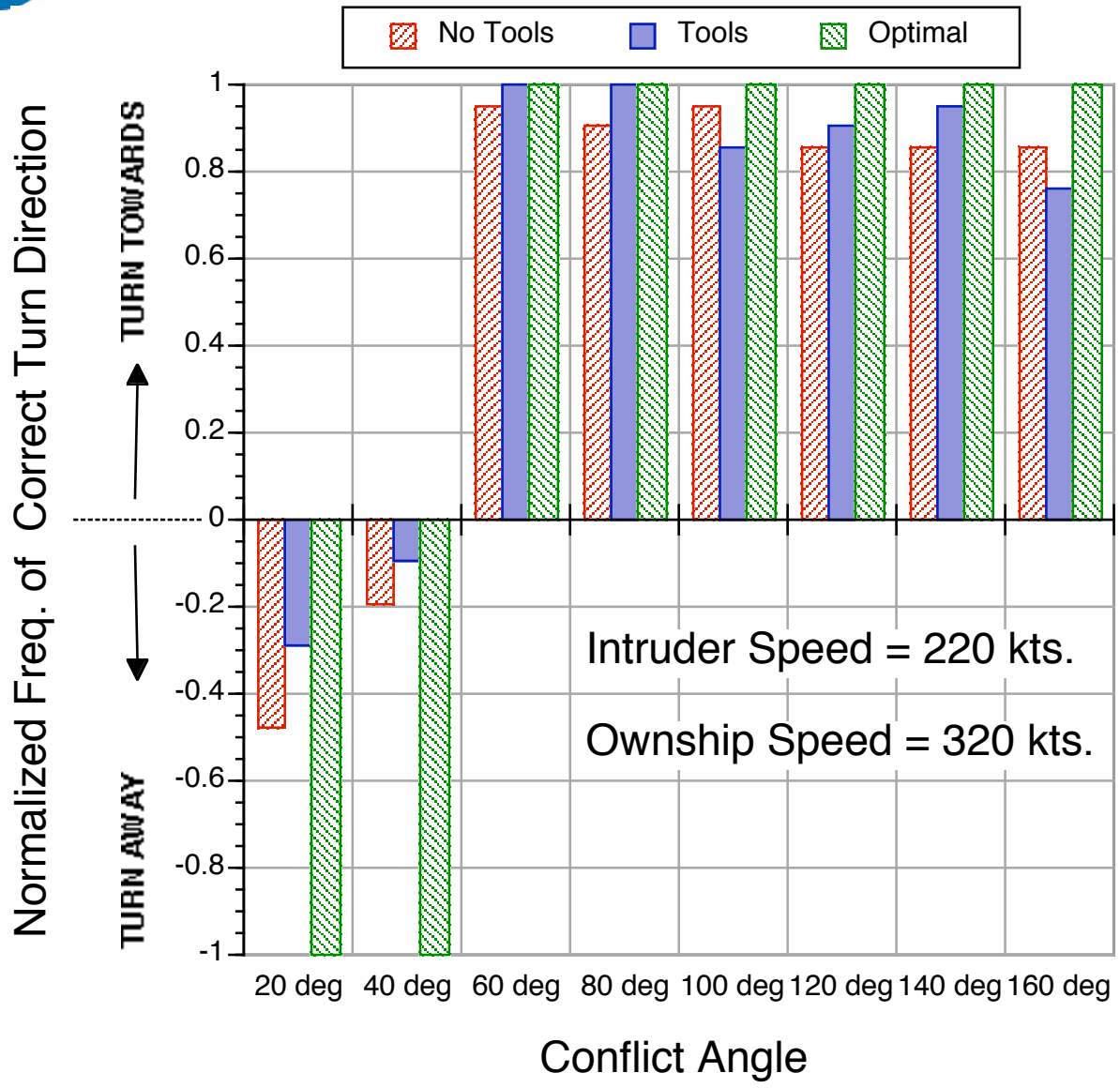
Closest Approach



Cost

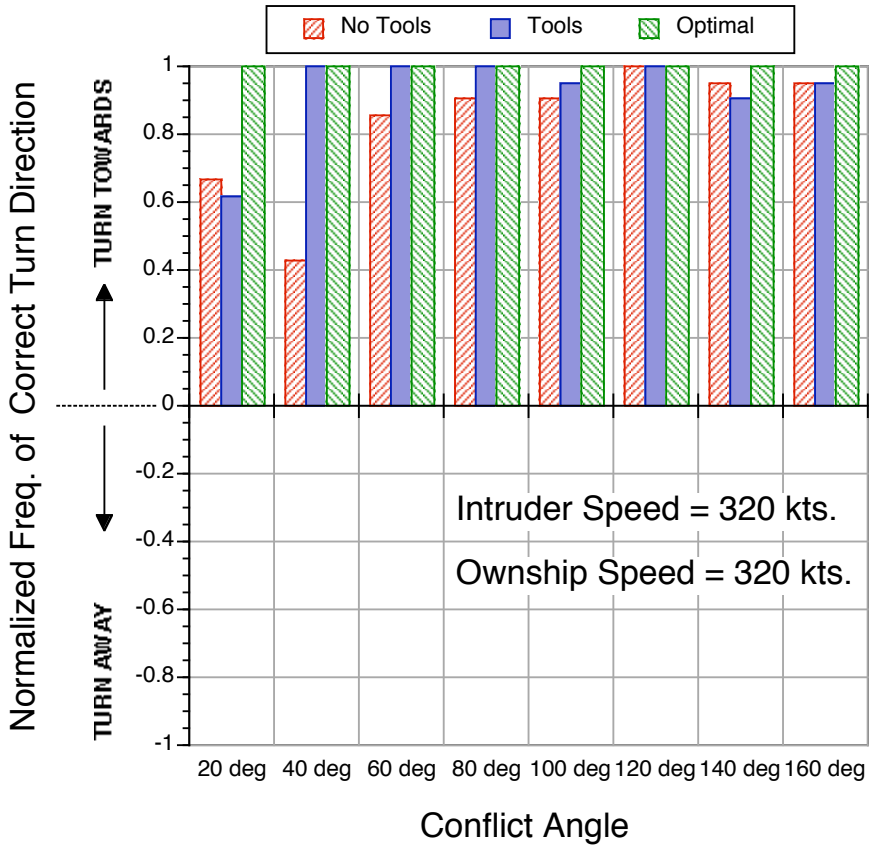


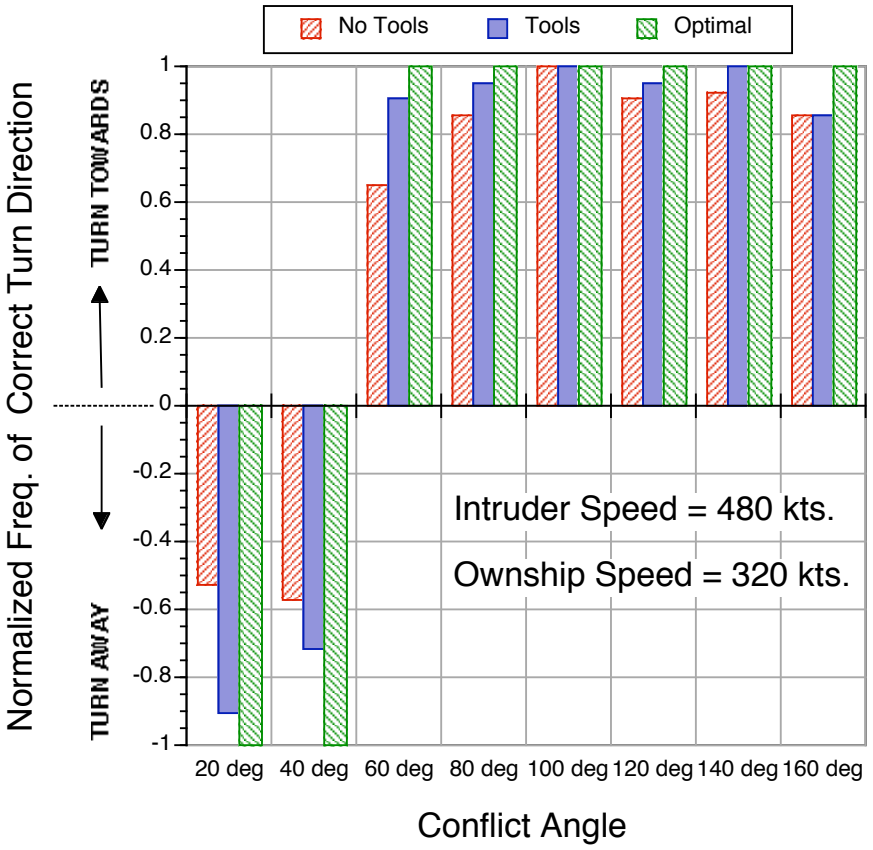
Turn Direction Analysis (1 of 3)



- Automation solution turns Ownship towards Intruder, except at low angles
- Turn directions of pilot solutions are consistent with automation solutions, except at low angles

Turn Direction Analysis (2 of 3)





Turn Direction Analysis (3 of 3)

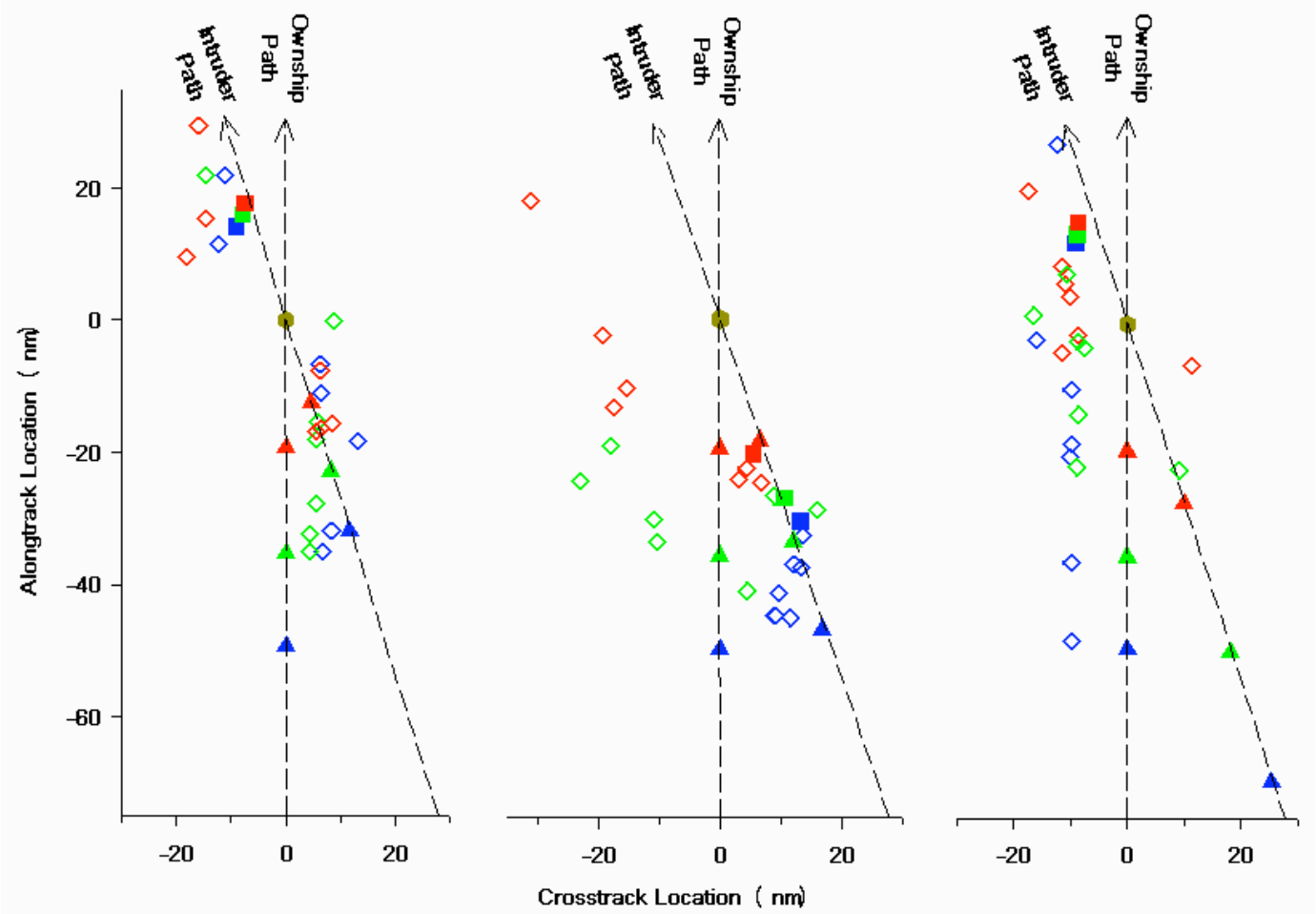
▲ Initial Aircraft Locations Locations

■ Automation-Generated Turn-Back

✹ Projected Collision Point

π Pilot-Generated Turn-Back Locations

Symbols color-coded by Ownship distance to collision: Red – Near Green – Mid Blue – Far



Conclusions

- Quality of pilot resolutions
  - Pilots successfully resolved all conflicts with angles greater than 90 deg, even without conflict resolution aids
  - At small conflict angles, need for resolution aids was clear
  - Pilot resolutions (even with aids) were not as efficient as automation resolutions

- Internal models of pilot and automation appear to differ

  While both automation and pilot resolutions generally turned towards the Intruder
  - Automation minimizes total path deviation
  - Pilots may be sensitive to only lateral path deviation component
  - More investigation needed to determine how fundamental these differences are (e.g., pilot training issues)

Discussion